An RF Quadrupole–Time-of-Flight System for Isobar-Separation and Multiplexed Operation of Experiments at Gas-Cell Facilities

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A novel system consisting of RF quadrupole and time-of-flight sections is proposed, in which ions can be cooled, bunched, mass separated with a resolution sufficient to differentiate between isobars, and guided to different experimental setups, e.g. for precision mass measurements or mass-selected decay spectroscopy of exotic nuclei. It enables multiplexed operation of several connected experiments and interleaved measurements using different nuclides in one connected experiment. Such a system could be employed advantageously at in-flight facilities, at which experiments with stopped exotic nuclei are made possible using gas-filled stopping cells, such as SHIPTRAP and the FRS Ion-Catcher at GSI or the LEB at FAIR, or potentially at ISOL facilities.

The system employs ion cooling, transfer and bunching in gas-filled RF quadrupoles. Curved quadrupoles allow to guide the ions into different directions to different experimental setups. Such a solution has recently been used successfully in an on-line experiment at the FRS Ion-Catcher. Isobar separation is effected in two stages, which consist of a low resolution RF mass filter and a high-resolution multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS) with a cycle time on the order of 1 ms. A small test version of such a MR-TOF-MS has been designed, built and tested. It consists of an electron-impact ion source, a time-of-flight analyzer with two electrostatic mirrors, and a microchannel plate detector. In initial tests, a mass resolving power of 35000 has been achieved. Transmission efficiency is limited currently mostly by collisional losses, which could be avoided by differential pumping. For an improved version of the MR-TOF-MS, a mass resolving power of 100000 is expected, sufficient for the resolution of most short-lived isobars. In order to operate the MR-TOF-MS as mass separator, the temporal resolution of the ions is converted to a spatial resolution using a pulsed ions gate. For multiplexed operation of several experiments, mass-selective transfer from an RF trap is used. While all incoming ions are accumulated and stored in this trap, ions with a selected mass number can be ejected and transmitted to an experiment, retaining the other ions in the RF trap. During successive cycles, different nuclides can be made available to one or several experiments, thus increasing the efficiency of the facility by making use of several nuclides rather than just one. Simulations and experimental results for individual stages of the system are presented.